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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

THE MODERN BUS AND TRUCK

Fuels and Lubricants
Part I

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

FREE ENTERPRISE

and the cost of gasoline

Courtesy S. F. Bouser & Co., Inc.

A GALLON of "gasolene" from the old-fashioned pump above (*circa* 1902) wouldn't drive a modern automotive engine very far. Yet it cost considerably more than today's vastly improved product. To back up that statement with figures, let's consider just the period between 1920* and 1952.

In those thirty-one years, U. S. gasoline prices, minus taxes, trended mostly downward under free enterprise, so that by the end of 1951 a gallon of gasoline cost almost 9½¢ a gallon less than in 1920. In the same period, *gasoline taxes increased 760%!* Yet despite this, the total cost of today's better gasoline is still about 2½¢ a gallon less—even without allowing for the fact that two gallons of today's motor fuel do the work of three of yesterday's.

The Texas Company is proud of the contributions made by its research scientists to the development of better gasolines at lower cost, including among others, the country's first really volatile gasoline, the improved Texaco Fire-Chief Gasoline and the revolutionary Texaco Sky Chief Gasoline.

You can look to Texaco for continued leadership in the development of motor fuels in the decades ahead.

*The first year for which accurate nation-wide records were kept. Figures based on average of prices in 50 leading cities.

THE TEXAS COMPANY

TEXACO

Faithfully yours for Fifty Years

1902 1952

LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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THE MODERN BUS AND TRUCK

Fuels and Lubricants

Part I

THE bus and truck industry manufactured over a million vehicles in 1941 and each year from 1947 through 1951. Records are not available regarding production 50 years ago, however, in 1904 AMA Records indicate that 700 units were sold. In the peak year of 1951 production was over 200,000% above that at the turn of the twentieth century. It is estimated that currently over 9.1 million busses and trucks are registered in the United States for on the highway use. The useful life of this equipment will depend on the care and attention it receives. Also the longer the life span of any unit can be increased without increasing service costs, the greater will be the return or earnings derived from its use.

Preventive maintenance (PM) is not a new idea. The principles as established more than 30 years ago set the pattern for present-day practices. As evidence we quote from an article in LUBRICATION back in March, 1921*, when approximately one million trucks and busses were in use, which contained the following remarks. ". . . in service where maximum reliability is essential . . ., the mechanical equipment is given a careful inspection at definite periods before trouble is expected to develop. These periods are determined by long experience as the shortest time the mechanism may be depended on to operate without danger to service. Inspection is made without waiting for trouble to develop. It is a common sense application of the principle of prevention. A good example of this type of inspection is presented by the routine of a certain well organized motor-bus transportation company, where every vehicle is given an inspection covering fuel, oil, water, etc., each morning; a general overhaul covering lubrication in detail, carbon removal, spark plugs, bearings, valves, etc., after each 2000 miles and a complete disassembly and rebuilding each year which represents approximately 30,000 miles."

Although today more power is obtained from smaller engines and transmitted through smaller transmissions and differentials, improvements in equipment design and fuels and lubricants have increased materially the miles between mechanical adjustments and tear-downs for most bus and truck operators. During the course of the past years there has been an increasingly close harmony between the

*Lubrication of Motor Vehicles — The Effects of Neglect

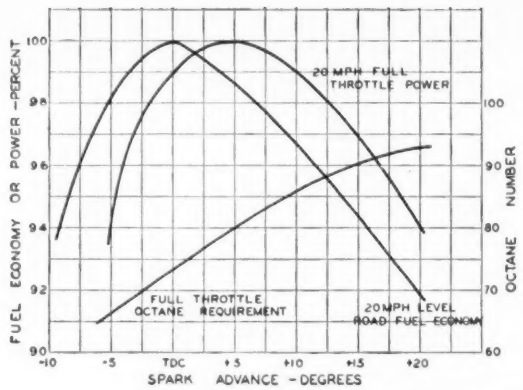

Figure 1 — Typical Gasoline Engine Power, Economy and Octane Requirement Curves.

mechanical designer and the fuels and lubricants developer so that their improvements parallel each other.

Most vehicle operators have learned of the advantages of PM and have set up definite procedures in accordance with their operation to service and maintain their equipment. All however, have not reached the point of maximum life and utility of their units. During periods of stress and national emergencies when shortages of new equipment existed many individual passenger car owners also were indoctrinated with the principles of PM. They realized that "a stitch in time saves nine" is equally as applicable to automotive equipment. Today many of them are requesting more and more information on how to best service and maintain their cars to obtain top performance for longer periods.

Since the correct fuels and lubricants properly applied are major factors in PM, the purpose of this article is primarily to discuss developments by which these products are being improved so that they may help prolong the usefulness of automotive equipment.

ENGINE FUELS

The engine is usually considered to be the most important component of an automotive vehicle since it supplies the motive power. It is also the most intricate component, it presents the most problems and it operates more than any of the other vehicle parts. The commercially available engines for bus and truck use are powered by either gasoline or Diesel fuel. The liquified petroleum gas (LPG) powered engine is considered to be in the gasoline category since it operates in the same manner although the fuel is handled differently and the engine may be modified somewhat to obtain the best performance from the use of LPG.

Although many people may contend that there is not much difference between the results obtained from any of these fuels, actually, the most suitable for any one type of operation is not necessarily the best for a fleet operating under different conditions. The selection of type of powering to be used must be made on the basis of a complete analysis which includes many factors. A few items that must be considered are: type of equipment in use and its expected life, overhaul and service facilities available, type of operation, first costs, cost of replacements and parts, availability and costs of fuel and local or area restrictions and regulations. This matter of selection of equipment requires considerable discussion which is far beyond the scope of this article. At present the majority of truck and bus engines are gasoline powered; a very small percentage are using liquified petroleum gases. Diesel fuel powering, although rapidly increasing in use, is still a distant second to gasoline.

MOTOR GASOLINE

Before the automotive engine demand for fuel arose, light petroleum fractions below the kerosine boiling range had little or no utility. By 1910 however the automotive engine fuel demands exceeded the demand for all other petroleum fractions. This created the need for increasing the yield of gasoline per barrel of crude. The solution was found in the cracking process which converts high molecular weight high boiling hydrocarbons into light fractions suitable as motor gasoline. The thermal cracking operation, the first type of cracking process used, is a process wherein at the same time as lighter hydrocarbons are formed heavier materials are also produced which are not susceptible to further cracking.

Later developments led to catalytic cracking. This accomplishes the same purpose in regard to breaking molecules but the direction of reactions is more carefully controlled through a catalyst or activating agent. As a result a greater yield of motor gasoline is obtained with less loss to heavy and very light molecules. Also, in this process the antiknock properties of the gasoline are enhanced due to the formation of certain types of hydrocarbons. Studies of the various reactions have led to the development of other processes such as polymerization, hydrogenation, alkylation, dehydrogenation, isomerization and cyclization or aromatization. All of these processes either join molecules, rearrange atoms in molecules or add or remove hydrogen

atoms in hydrocarbon molecules to obtain the specific hydrocarbon structure desired. As a result of these processes it has been possible to increase the yield of gasoline from petroleum crude economically while providing improved motor gasolines for engine fuel.

The modern motor gasoline is considered as containing a mixture of hydrocarbons, this mixture having a boiling range within the extreme limits of about 90°F to 420°F as noted in Table I. It is recognized that the values shown in this table may vary depending on their source. Some of the hydrocarbons present may boil considerably below 90°F but these materials are usually present in relatively small percentages and do not significantly change the nominal boiling range noted. The hydrocarbon molecules present may range from four carbon atoms to as high as twelve to sixteen carbon atoms.

The stocks used to blend these fuels as they come from stills or manufacturing units contain constituents that are undesirable in motor fuels and must be removed or treated to render them harmless to the engine parts.

A gasoline engine can be made to run on almost any kind of gasoline provided it can be started and uneven operation is unheeded, but, reliability, flexibility, economy and smoothness are prime requirements of satisfactory operation and optimum engine life. These characteristics depend jointly on qualities of the gasoline and the mechanical and operating conditions of the engine. The major characteristics of motor gasoline that govern its quality performance-wise are octane rating and volatility. The octane rating is governed to a great extent by the types of hydrocarbons present and may be improved within limits by the addition of tetraethyl lead. The volatility is controlled by the relative amounts of high and low boiling molecules used in the blend.

Octane Rating

Gasoline octane rating should be above that demanded by the engine; marked increases in antiknock qualities however, serve no purpose. The practice of increasing spark advance beyond the engine manufacturer's recommendation when the octane rating of motor gasoline is well above the engine demand may easily result in loss of power followed by a rapid loss in economy with further small spark advances. This may be noted from the typical power, economy and full throttle octane requirement curves for various spark advances shown as Fig. 1. In addition, operating temperatures are influenced considerably by spark advance.

Too low an octane rating will result in engine "knock" or "ping," under certain conditions of operation, with attendant loss in power, engine overheating and possibly damaged gaskets, pistons and bearings. Typical detonation failures are shown as Fig. 2. If it is not possible to obtain motor gasoline of sufficient octane rating then corrective measures should be applied to the engine such as, adjustment of ignition timing (retard), or adjustment of carburetor mixtures (richen).

Preignition

It is of interest to note that some engine "knocks"

TABLE I

Typical Characteristics of Automotive Fuels

Name	*Gravity °API*	*Boiling Point °F.*	*Vapor Pressure @ 100°F. psi abs.*	*Specific Gravity 60/60°F.*	*Specific Weight @ 60°F. lb./gal.*	*Lower Heating Value*		*Octane Number*	
						BTU/lb.	*BTU/gal.*	*Research*	*Motor*
Propane	147	—44	184	0.508	4.23	19,670	83,340	100 + 1.9 ML-TEL	97
Butane	111	31	52	0.584	4.86	19,470	94,670	94	90
Motor Gasoline	60	90-420	6-15 (Reid)	0.74	6.16	18,900	116,400	75-95	70-87
Kerosine	42	300-500	Less Than 1.0 (Reid)	0.82	6.79	18,560	126,200	—	—
Diesel Fuel	35	350-650	Less Than 1.0 (Reid)	0.85	7.08	18,390	130,300	—	—

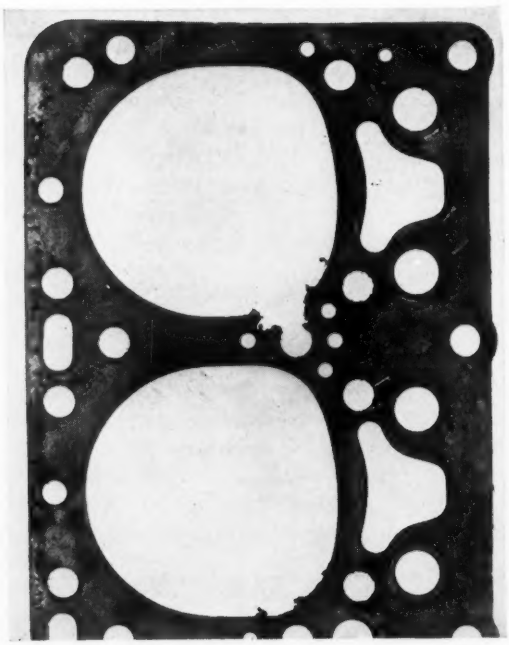

Figure 2 — Typical Failures Resulting from Fuel Detonation, see effect on piston (above); and on gasket (below).

may be of a mechanical nature and the inexperienced listener may attribute them to the fuel. Also, if the engine is mechanically normal a fuel "knock" may also result from preignition. Preignition means the initiating of combustion before and by some means other than the properly timed spark at the plug; detonation is the term applied to "knock" caused by a too low octane rating of the fuel. Preignition is generally caused by localized overheating at some point such as exhaust valve heads, spark plug electrodes, high spots on the piston or cylinder head or incandescent deposits. It is not improbable that some supposed detonation may actually be traced to hot spots due to clogged engine coolant passages,* excessive spark retardation causing increased combustion temperatures, insufficient or improper cleaning of spark plugs with the resultant formation of carbon that may incandesce, and the use of improper spark plug gaskets or complete absence thereof preventing proper heat transfer.

Volatility

Volatility affects starting, warm-up, vapor-lock, crankcase dilution, uniform performance, acceleration and complete combustion. Assuming that the mechanical condition of the engine is normal, a properly timed spark is supplied and other factors such as oil viscosity and battery strength permit the engine to be turned over, then the temperature at which 10% of the gasoline is evaporated permits estimating the lowest atmospheric temperature at which the engine will start. Acceleration and warm-up are governed primarily by the 50% evaporation point of the gasoline although affected somewhat by the 10% point. The 90% evaporated and end points affect distribution, completeness of burning (crankcase dilution), and may affect acceleration. Vapor-lock is usually associated with vapor pressure, however, since vapor pressure is related to the boiling points of the hydrocarbons present, vapor-lock also depends on volatility. It is obvious that gasoline must evaporate quickly but not excessively so as to cause vapor-lock. At the same time insufficient vaporization in addition to giving poor power performance may lead to damaging of the engine since fuel in the liquid state can wash away lubricating oil from the cylinder walls, rings and other parts and dilute the crankcase oil.

*This is a major reason for periodically cleaning the engine coolant system.

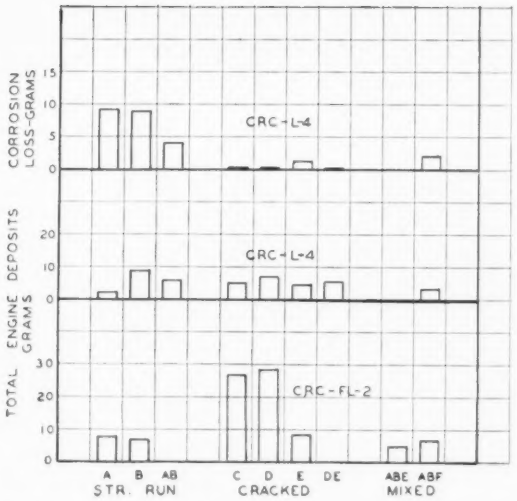

Figure 3 — Effect of Motor Gasoline Types on Engine Deposits and Bearing Corrosion at Different Engine Temperature Levels.

Motor Gasoline Performance

The engine imposes different requirements of volatility and octane number depending on the season (temperature) and the altitude so it is obvious that the gasoline marketer must tailor his product according to seasons and areas. Since truck and bus engines in general are not as demanding as passenger car engines and gasolines are marketed to meet the requirements of the latter, the transportation field should have no particular difficulty in obtaining suitable gasolines.

In the past ten years it has been found that in addition to power performance gasolines contribute to engine deposits and copper lead bearing corrosion. The extent of the effect depends on engine operating conditions. Some data on these effects obtained in laboratory engine tests are shown in Fig. 3. It is pointed out that the fuels used were stocks obtained for laboratory purposes and the blends noted are not typical of any particular commercial motor fuels. By visual observation the engines appeared to be clean when total deposits as high as nine grams were evenly distributed on engine parts. In the corrosion test the weight losses below 0.5 gram are considered to be non-corrosive normal wear losses.

From these data it may be noted that under low temperature engine conditions straight run stocks tend to produce little or no engine deposits while certain cracked stocks may be heavy offenders. Un-

Figure 4 — Dirty vs. Clean Engine from Low Temperature Operating Conditions, Showing Fuel Effect, with all other conditions constant.

der these low temperature engine operating conditions in the laboratory, alloy bearing corrosion has never been reported. Under high temperature engine conditions most fuels showed no significant effect on deposit formation but straight run fuels promoted alloy bearing corrosion. The difference in deposit formation attributed to the fuel in use under low temperature condition may be noted in Fig. 4.

Commercially available gasolines from reputable marketers appear to minimize these undesirable effects. It has been found that engine operation completely within the manufacturer's recommendations and ratings for coolant temperature, fuel-air ratio, timing and power demands, tend to minimize these deleterious effects. The use of proper motor oils drained at the right frequency also alleviate or minimize these conditions.

The most recent problem being investigated in the gasoline engine field is that of combustion chamber deposits which tend to increase the octane requirement of an engine. At present it seems that the causes of this are a reduction in engine clearance volume and increased temperatures resulting from the insulating effect provided by the deposits. Since this imposes a limit on increasing engine compression ratios, with the motor gasolines available today, a method of minimizing these deposits is very desirable. The oil industry, fuel additive suppliers and engine builders are actively studying this problem.

Liquefied Petroleum Gases

Natural gases and light petroleum hydrocarbons have been used for powering engines for a number of years. Both Diesel and gasoline engines have been converted to this type of fuel powering. In the automotive field engine conversions to this type of powering were reported more than twenty years ago, however, in the last two or three years a large increase in use of LPG has occurred and wide interest on the subject has resulted. The interest was undoubtedly greatly spurred by a bus manufacturer whose engine was designed for high compression ratios and was easily modified to utilize propane. Another engine was announced as being suitably designed for propane. Conversion kits are available for practically all makes of automotive engines, although compression ratios of most engines cannot be materially increased so as to obtain full advantage by using propane. In the truck field an engine modified for butane and propane powering has been available for quite some time. In 1952 propane powered trucks as factory equipment approved by the Board of Fire Underwriters were announced.

The questions most generally asked are "What is LPG?" and "What are Liquified Petroleum Gases?" It is quite obvious that these questions are identical since LPG is the alphabetical representation of the name; a common way of referring to long names that has crept into our language in the past twenty years. In general LPG is predominantly either propane or butane with minor amounts of the other gases and perhaps very small amounts of heavier C_5 hydrocarbons (5 carbon atoms per molecule). When these gases are pressurized they assume a liquid state which is more suitable and economical for handling. The amount of pressure required for complete liquifaction varies with the composition. These gases as obtained in a natural state or from petroleum refining processes may contain impurities such as sulfur compounds and other contaminants which may be injurious to engine parts. The engine operator who uses LPG should have some assurance that these contaminants are minimized and that the composition of the fuel is constant since each of these gases has somewhat different characteristics as may be noted by the values for propane and butane shown in Table I.

It may be noted from Table I that at temperatures below 31°F at standard atmospheric pressure butane is normally in a liquid state and does not vaporize quickly enough to respond to engine demands. This fuel would be of little use to an engine equipped with a gas type carburetor at temperatures below 32°F unless a means of heating the fuel is provided. An easier solution would be to include some lighter gas like propane to lower the boiling point and increase vaporization of the fuel. Basis the vapor pressure of these two gases it is obvious that a lighter fuel tank (lower pressure) may be used for butane, however, for safety reasons it is wisest to use tanks able to sustain the worst pressure condition encountered. If definite codes are not established in any particular area, fuel tanks should be built in accordance with the API-ASME code for 250 lbs. tanks.

LPG fuel tanks should never be filled 100% full. A 10% to 20% vapor space must be allowed for expansion of the fuel with temperature increases. The larger value should be used if temperature variations may approach a 100°F spread. Some manufacturers include a "full" valve to indicate when the expansion space has been reached in filling. This type may be noted installed in the tank

shown in Fig. 5. When filling this type of tank, vapor is allowed to escape through the full valve. When the valve starts to drain liquid fuel, filling should be stopped as the expansion space has been reached. Another manufacturer includes an inner tank called an outage tank and the fill valve is arranged so that it seals off this expansion space during tank filling.

Propane and butane have higher heating values per pound of fuel than motor gasoline, therefore at the same compression ratio in a given engine at optimum conditions for each fuel it might be expected that for the same power more motor gasoline is required but since slightly different air-fuel mixtures are necessary economy on a power per pound of fuel basis is approximately equivalent for these fuels. In service, however, fuel economy is measured on a miles per gallon basis which would give motor gasoline approximately a 16% to 24% economy advantage depending on the composition of the LPG. By utilizing the higher octane ratings of LPG, particularly when it consists mainly of propane, and by using higher compression ratios to obtain more power per pound of fuel it is possible to improve LPG economy. It is claimed that in some cases in service MPG economies of propane and motor gasoline are equivalent. It is strongly stressed that before any attempt is made to increase compression ratios of any engine more than one number the engine manufacturer should be consulted in regards to the advisability of the proposed modification.

In converting to the use of LPG some other points must be considered such as ignition timing. LPG has a higher ignition temperature than motor gasoline therefore a hotter spark is required. This means that the ignition system must be kept in the best possible condition at all times. Also, spark timing must be adjusted for optimum performance from LPG. Hotter combustion temperatures are experienced which may require use of a "colder" spark plug and better valve materials and valve condition. Since the fuel is fed to the engine in a vapor state, manifold hot spots are not necessary and should be eliminated so as to obtain maximum volumetric efficiency. If the engine is to be used for both motor gasoline and LPG then some compromise must be made. Engine coolant temperatures must be kept high as will be noted below.

For practical reasons such as space saving LPG must be carried in the liquid state, however, it is best fed to the engine in a vapor state. The pressures in the fuel tank are too high to be applied directly to a carburetor and enough vaporized fuel is not readily available in the fuel tank to respond to the varied demands of an engine in automotive service. The transfer of fuel to the engine is usually done in four stages as may be noted in Fig. 5. The

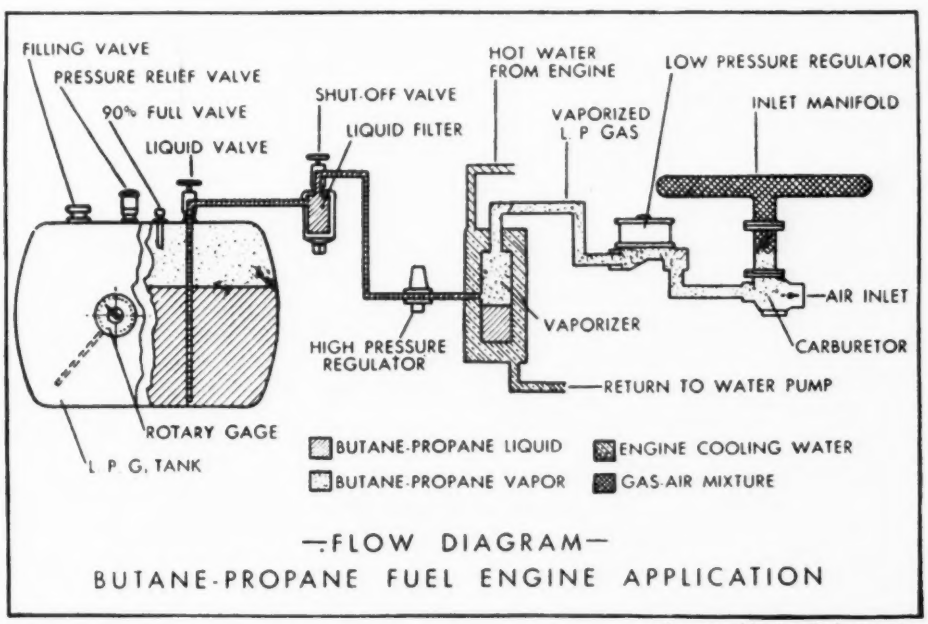

Figure 5

Courtesy of Ensign Carburetor Co.

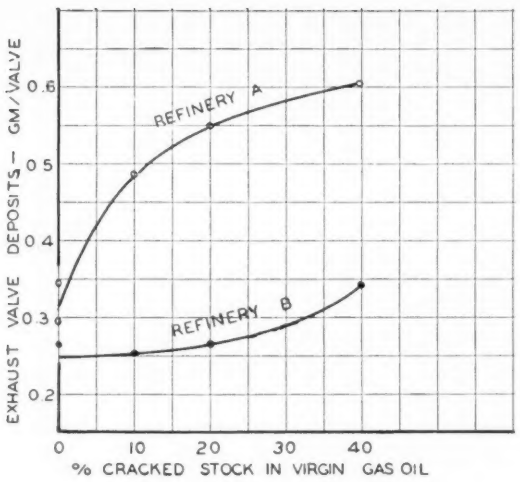

Figure 6 – Effect on Exhaust Valve Deposits of Increasing Cracked Stock Concentration in Virgin Gas Oils.

tank pressure of from 20 to 175 pounds must first be reduced to a regulated 4 to 10 pounds. The fuel is then allowed to vaporize rapidly. In expanding and vaporizing a refrigerating effect is created which could freeze up the mechanisms involved therefore, the vaporizer must be heated. Heat is supplied from the engine coolant which is the reason for the higher jacket temperatures required in LPG service. The vaporized fuel must then be reduced in pressure from the regulated pressure to one slightly below atmospheric. This final regulator must shut off fuel below atmospheric pressure to prevent leakage and must be designed so that it will instantly permit vaporized gas to flow to the carburetor in metered volumes to conform to every engine demand. The last stage is carburetion which not only must mix fuel and air but must proportion the mixture to the right air-fuel ratio. It is quite obvious that these four stages may be combined so that more than one step is accomplished in one piece of mechanism.

The best systems should have perfect coordination between the final pressure regulation and carburetor throughout the entire range of engine speeds and loads, from fast acceleration to full throttle and back to idle. Flow characteristics must be similar to motor gasoline operation, that is rich for heavy loads and leaner for cruising, and must be instantaneous without over-richness or lean flat-spot operation. Since this type of operation requires many sensitive valve actions it is obvious that a filter is a definite necessity and one usually is placed immediately beyond the fuel tank.

From the nature of LPG it would be expected that combustion should be complete with no engine deposits, no cylinder wall washing and no crankcase contamination. In practice, however, complete combustion is not always attained and the products formed will get into the crankcase as blowby material. Unless combustion is very poor and blowby excessive it is expected that these products would not materially increase engine deposits. However butane and propane are straight chain hydrocarbons of the same type as are found in straight run gasolines, and the type of incomplete combustion materials formed upon entrainment in the lubricating oil can lead to alloy bearing corrosion. This may be noted from the data shown in Table II which are the results of evaluating a commercial grade of propane in the CRC-L-4 test. Note that a MIL-0-2104 oxidation stability level oil which was very satisfactory in this test using the normal L-4 test gasoline did not offset the effect on bearing corrosion of the fuel. It is obvious that for utmost protection high quality heavy duty oils should be used in LPG engine service.

Diesel Fuels

The early Diesel engines were mainly large slow-speed machines that were not too particular about their fuel diet. With the advent of the automotive high speed Diesel engine about twenty years ago the problem of obtaining a proper fuel became difficult for the operator. Due to the shorter interval of time available for combustion the high speed Diesel could not satisfactorily burn the fuel oils commonly used in the larger slow-speed engines. The 400°F to 700°F fraction of petroleum crude distillation appeared to be a more desirable fuel oil for high speed engine service. However this same cut is the one that is used in cracking processes to meet the gasoline demands; furthermore the heavy hydrocarbons from the cracking process are still suitable for the low-speed engine. Light furnace oils were considered to be unsuitable since their lower viscosities appeared to be insufficient for injector lubrication. Ordinary methods of handling fuel oils resulted in products that were not sufficiently free of contaminants. Worst of all there was no uniformity of fuels as marketed in different areas even among those under the same trade name. Therefore it became necessary for the fuel supplier to provide better fuels specifically tailored for the high speed Diesel engine.

The characteristics of a Diesel fuel which must be considered are:

Pour Point – Below lowest temperature encountered so fuel will flow.

Viscosity – Sufficiently low to flow freely at lowest temperatures. High enough to lubricate injection system and prevent leakage. Correct for atomization and penetration requirements of the combustion chamber.

Cetane Number – Sufficiently high for satisfactory starting and proper combustion.

Gravity – Should be as low in API gravity as possible for maximum economy. Usually this requirement is waived to secure fuels of proper viscosity and ignition quality, as the difference in economy with different fuels may be rather small.

Carbon Residue – Low for clean combustion.

Corrosion – Free from corrosive materials.

Flash Point – Above legal requirement for safety.

Sediment – Should be nil.

For automotive Diesel service it appears that fuel oils meeting the requirements of the ASTM-2D classification are satisfactory for over-the-road service while those in the ASTM-1D classification are most suited for operation within city limits particularly when smoke and exhaust odors are a problem. Distillate fuels containing no residual products and of sufficient ignition qualities (cetane number) when used in engines in proper mechanical condition achieve complete combustion with clear exhaust gases and a minimum of deposits. Many believe that cracked fuel oils, even when sufficient lubricating and ignition properties are available, are undesirable engine fuels since they promote deposits. This is not necessarily true as will be discussed later. As a result of the stringent requirements, the supply of the ideal fuels is naturally limited.

Starting Aids and Fuel Improvers

After an automotive Diesel engine has been started and operating temperatures have reached an equilibrium the engine will tolerate a wider range of fuels. Many innovations have been used in engine designs so as to be able to start on these fuels. Some of these methods and devices used are "punks" electrical air heaters, glow plugs, variable compression devices (starting on gasoline), coolant heaters and flame primers.

Starting capsules, primer and booster fuels and pilot injection are other methods used to aid starting with a wider range of fuels. These methods involve special injectors or pressure guns feeding the air stream or directly into the combustion chamber, some only at cranking time, others during certain portions of power demand, and some con-

TABLE II

CRC-L-4 Test Results – Commercial LPG vs. Test Gasoline

	Commercial LPG		*L-4 Fuel*
Oil	*Highly Refined Straight Mineral SAE 30*	*MIL-0-2104 Oxidation Stability SAE 30*	*MIL-0-2104 Oxidation Stability SAE 30*
Cleanliness Rating			
Piston*	8.2	9.5	9.0
Overall**	90	90	89
Bearing Corrosion			
Gms/2 whole bearings	8.373	2.366	0.180
Neutralization No. Increase	5.4	3.2	2.2
Viscosity SUS @ 210°F Increase	36	68	3

* 10 = Completely clean
** 100 = Completely clean

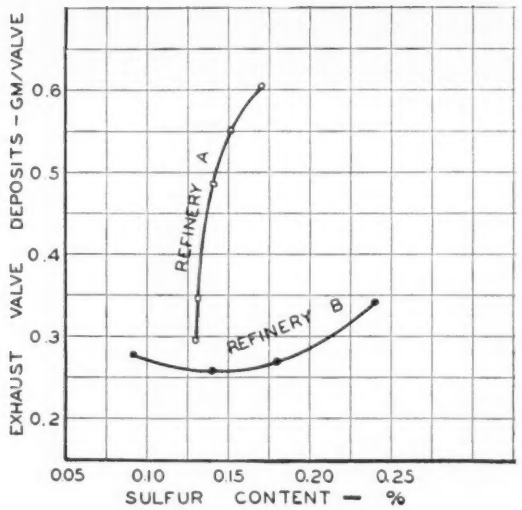

Figure 7 — Effect on Exhaust Valve Deposits of Fuel Sulfur Content.

tinuously. Some of the starting aids available produce high peak pressures in cylinders and, although the engine may tolerate these loads during starting, early engine failure may result if used during regular engine operation. The operator is advised to consult the engine manufacturer before incorporating these methods in his operation.

Additive materials have been found which, when added to a Diesel fuel, upgrade the cetane number. Since cetane number is a measure of the ignition quality of Diesel fuels it would appear that the use of additives is advisable. Laboratory and field experience with "doped" fuels however produce many contradictory results as to startability, power performance and economy, and also many cases of increased objectionable deposits have been traced to these materials. If the operator is using a fuel that is tailored to his engine requirements he should never "dope" it up since in most cases he will be degrading his fuel.

Much has been said about the deleterious effects of sulfur in Diesel fuel on engine performance particularly with respect to deposits and wear. However it is believed that most people have learned that the alarm gong sounded a few years ago is now a mere tinkle. Most engines if operated according to manufacturer's recommendations will tolerate a much higher fuel sulfur content than was at first thought. Also, the oil industry has developed motor oils to offset effectively deleterious effects for cases where the engine is sensitive to sulfur in the fuel. In view of this no further comments on this subject are deemed necessary.

Cracked Fuels

Approximately five or six years ago it appeared as though the increase in use of high speed Diesel power would create a serious fuel supply problem for the oil industry. Subsequent findings revealed that much of this equipment was not as particular about its fuel as had been anticipated so the supply situation was eased considerably. However, at the time of the threatening emergency work had to be done in an effort to obtain greater yields of automotive grade Diesel fuel without interfering with supplies of other fuels. The problem was attacked from two sides: utilization of available refinery stocks, and improvement of refining methods. In view of the present sharp increase in use of Diesel powering for trucks and busses the results of these investigations may be of interest.

When future demands appeared to exceed the available supply of virgin gas oils (distillate fuels), light cycle gas oils (cracked stocks) were available with physical properties approaching those of virgin gas oils. Common thinking was that these cracked materials would promote heavy engine deposits. Therefore, it appeared desirable to actually determine whether small amounts of cracked stocks would degrade the performance quality of virgin gas oils. Accordingly stocks were obtained from two refineries whose crude sources were widely different.

In blending these stocks it was found that up to 40% of the cracked stocks could be included in the virgin gas oil from each refinery and still obtain the physical characteristics of an excellent automotive Diesel fuel. The next step was to determine what effect on engine performance these blends would have. To do this the CRC-F-18 test procedure was followed using a two cycle three cylinder engine coupled to an absorption dynamometer and equipped with necessary instruments and controls to obtain the desired operation. The major operating conditions for this test as applied to the engine used were as follows:

Test Duration, Hours	80
Operating Cycle	3 min. at 350 RPM—No Load 7 min. at 1600 RPM—58 BHP
Jacket Temperature, Out, °F	180
Oil Temperature, °F	200

The crankcase oil used was one that is qualified against the MIL-0-2104 specification normally recommended by the manufacturer for this type engine. The test differentiates differences in fuel performance with respect to deposit formation, exhaust smoke and odor and engine wear. The results showed no significant differences in performance between the 40% light cycle gas oil blends and the virgin gas oil stocks.

The testing could have been terminated at this point but to assure quality of the fuel it was necessary to carry out further engine tests that magnify differences in deposit forming characteristics. It is well known that under light loads and moderate or low temperature conditions Diesel engines will promote injector tip and valve deposits. Accordingly assorted blends containing up to 40% cracked stocks were evaluated in a two cycle one cylinder engine following a special test method whose major operating conditions are as follows:

Test Duration, Hours	100
Engine Speed, RPM	1200
Engine Load, BHP	5 (23.3 BMEP)
Jacket Temperature, Out °F	140
Oil Temperature, °F	205

The MIL-0-2104 qualified oil used in the previous tests was used in this engine.

The results obtained are shown in Fig. 6 which indicates the weighed exhaust valve deposits formed plotted against increasing cracked stock content of the fuel. It is quite obvious that a difference in deposit formation of fuels from different crude sources existed and the effect of cracked stocks from Refinery A were more pronounced. To assure highest quality the cracked stocks from Refinery A should be kept at a minimum while at Refinery B, in case demands were to increase, up to 40% of cracked stocks would be tolerable. No significant differences in injector deposits among these blends were noted; all were low.

In view of the interest in fuel sulfur content the deposit data were compared to the sulfur contents of the blends. This comparison is shown as Fig. 7. The data obtained were very consistent and indi-

TABLE III

Effect of Furfural Refining of Catalytically Cracked Stocks

Fuel	*Raw Charge Stock*	*Furfural Refined Stock*	*Commercial ASTM-2D Automotive Diesel Fuel*
Gravity, °API	26.50	38.9	39.2
Viscosity, Kin. @ 100°F, cs	2.79	2.87	2.61
Sulfur, %	0.65	0.11	0.34
Flash Point, °F	220	190	168
ASTM Distillation, IBP°F	420	411	380
10% Recovered, °F	476	453	424
50%	509	508	502
90%	592	588	570
End Point	636	628	602
% Recovered	98.0	99.0	98.5
Cetane Number	35.0	54.0	54.8
Carbon Residue (10% Resid)	0.27	0.03	0.02
Water and Sediment, %	0.20	Trace	Trace

cated no correlation between amount of deposit and sulfur content as evidenced by the appreciable differences in deposits between fuel stocks having the same sulfur content. The trend of the curves, however, may indicate a possible small effect from the presence of sulfur, for Refinery B; but a very considerable effect for Refinery A.

To round out the program the fuels were subjected to stability and storage tests which showed no significant differences among the various blends.

Concurrent with this investigation pilot plant work was being done on solvent refining of Diesel and domestic heating fuel oils. The refining technique involved the furfural process. This process improves catalytic cracked stocks to virgin gas oil quality as may be noted from Table III. Note the reduction in sulfur content, the cetane number improvement and the reduction of undesirable materials. Also, compare this furfural refined product to the commercially available automotive Diesel fuel. The three fuels shown in Table III were compared by the low load engine test and the following results were obtained.

Fuel	*Exhaust Valve Deposits Per Valve — Grams*
Raw Charge Stock	0.581
Furfural Refined Stock	0.127
Automotive Diesel Fuel	0.327

The improvement is obvious; also note how well the commercial automotive Diesel fuel deposits compare with those obtained on virgin gas oils shown in Fig. 6. Some injector tip deposits were formed by the raw charge stock while the other two fuels left only traces of soot. Photographs of typical valves from this test are shown as Fig. 8.

All of the used crankcase oils showed no significant deterioration while these tests were conducted, as was expected from the oil used.

These data show that actual performance disproves the general thinking that all cracked fuels are undesirable Diesel engine fuels.

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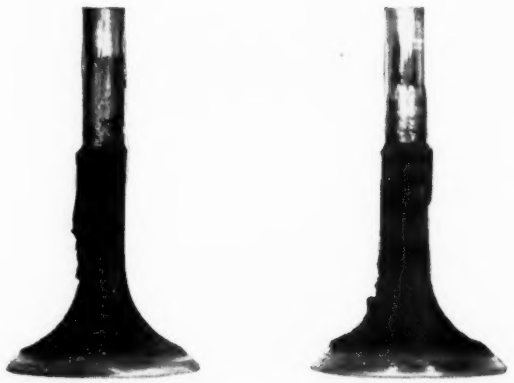
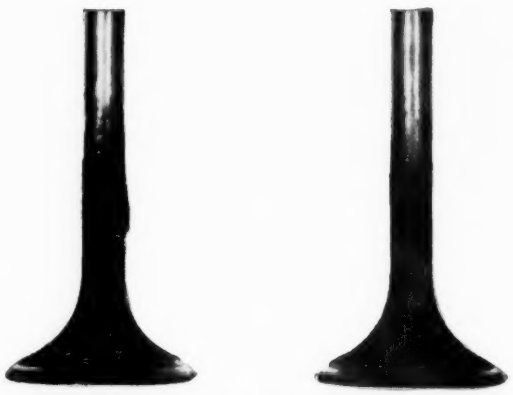
This completes the discussion on fuels for bus and truck engines. The lubricants for automotive equipment will be covered in next month's issue of LUBRICATION therefore a summary of the foregoing material is deferred until then.



Raw Charge Stock.



Furfural Refined Fuel Oil.

Automotive Diesel Fuel.

Fig. 8—Diesel Engine Exhaust Valve Deposits—Low Load Test.

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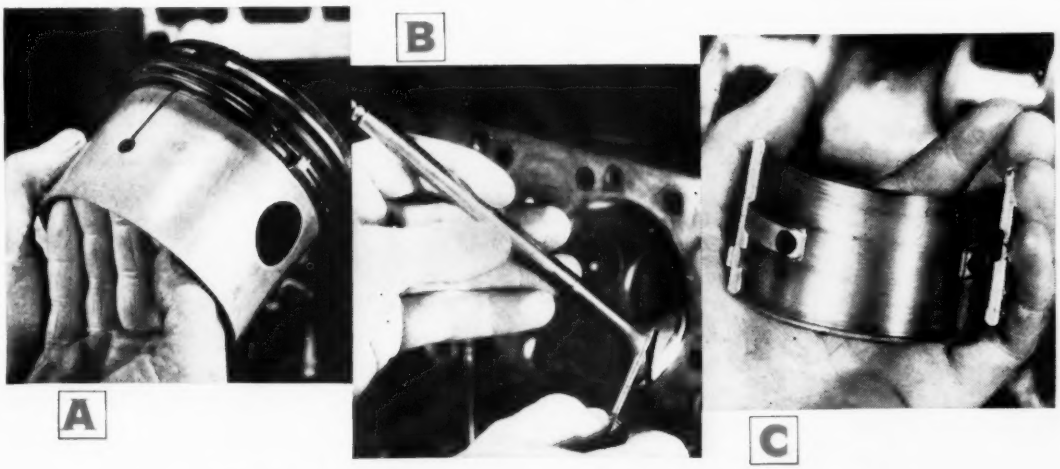

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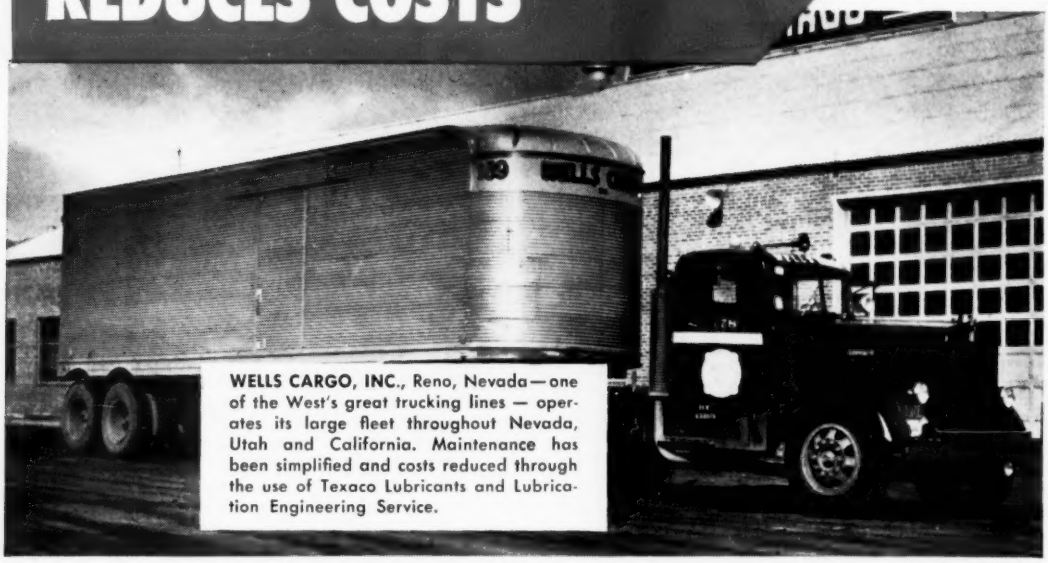

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